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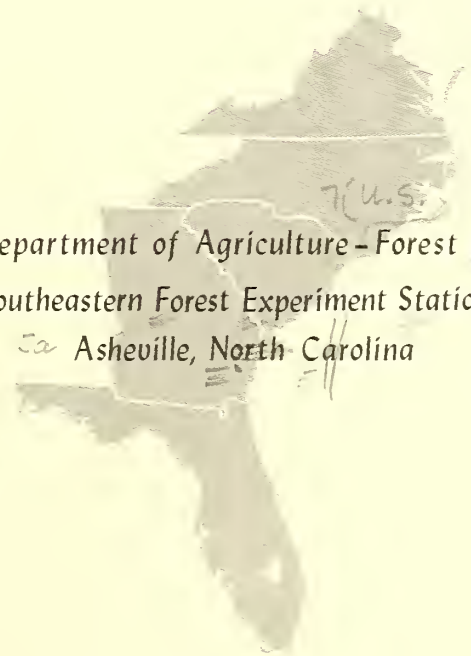

U.S. Department of Agriculture - Forest Service
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Asheville, North Carolina

Tests on Direct Seeding of Oak in the Piedmont and Southern Appalachians of North Carolina

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For too many years there has been relatively little interest in the regeneration of commercial hardwoods in the United States. Because of the rising emphasis on hardwood management, and following the success attained in regenerating conifers by direct seeding, foresters have recently begun to ask for information on inexpensive methods of hardwood regeneration and forestation. This paper reports the results of three direct seeding tests of oak, one in the upper Piedmont and two in the southern Appalachians of North Carolina.[1/]

Of the limited study results available on the direct seeding of oaks perhaps the most valuable is one by Korstian (1927), an intensive study of the factors affecting germination and survival of white and black oak groups. The work, done at Asheville, North Carolina, and New Haven, Connecticut, showed that up to 90 or 100 percent of the acorn crop may be destroyed by animals and insects. Field tests and observations indicated that screens were of little benefit in protecting acorns against rodents, and that a cover of leaf litter or soil was necessary for successful germination and survival of the acorns.

In a test in east-central Iowa, destruction of northern red oak acorns by rodents was severe on unprotected spots (Krajicek, 1955). Unprotected fall-sown acorns on the surface or in the leaf litter were almost completely destroyed, while those planted 1 inch deep, with litter replaced, were 68 percent destroyed. Acorns protected by screens were not eaten, but when the screens were removed in the spring, up to 75 percent of the germinated acorns were destroyed by rodents. Insects further reduced the survival to 5.6 percent.

Engle and Clark (1959) tested rodent repellents on red oak acorns in southern Indiana. Seeds were planted in the spring and fall of 1958 and spring of 1959 in a half-acre opening in an oak-hickory stand. Spring planting was with stratified nuts; depth of planting was 1 inch. Rodents were abundant. The repellents tested, Endrin and Thiram, failed to reduce rodent pilferage; in fact, untreated seeds produced more seedlings than

1/ Grateful acknowledgement is due the Furniture, Plywood and Veneer Council of the N. C. Forestry Association for valuable assistance in the Piedmont study.

treated seeds. There was a striking difference between results for the 2 years; in the spring 1958 planting, 37 percent of the red oak survived, compared with 9 percent for the spring 1959 planting. There was a good hickory crop in 1957, but practically none in 1958.

The direct seeding of important bottomland oak species is being studied in South Carolina (Klawitter, 1959). Results indicate that seedlings from direct seeded acorns grow as well as or better than planted seedlings; 20 percent of the planted acorns survived as seedlings compared with 58 percent survival for planted seedlings. Clearing before seeding gave higher survival and growth rates than seeding under a residual stand with later release. Survival was lower on the wet areas than on the better-drained areas.

These study results point out some of the problems involved in direct seeding of acorns and indicate that the method does hold promise for regeneration of the oaks. There is need for more research to develop the best techniques for each species or species group in the varying conditions found in its range.

METHODS

Acorns of white oak (Quercus alba L.), black oak (Q. velutina Lam.), and northern red oak (Q. rubra L.) were collected during the fall of 1956 near Statesville, North Carolina, for the Piedmont study. Northern red oak acorns, the only species used in the two mountain studies, were collected at Bent Creek, near Asheville, North Carolina, during the fall of 1958 for the first study and during the fall of 1959 for the second study.

All acorns were immersed in water; those that floated were considered defective and were discarded. The remainder were treated with a hot water bath at 120° F. for 40 minutes for weevil control.

Piedmont

In the Piedmont study near Statesville, North Carolina, the white oak acorns were sown in the fall (fig. 1). The black and northern red oak acorns were stratified in moist sand in November, and the sprouted acorns were sown on March 26 the following spring. All acorns were planted three-fourths of an inch in mineral soil and the litter replaced.

Seeding was done on four different cover types to determine if rodent populations and acorn germination and survival varied by cover type. The following cover types were used:

1. Old field.
2. 4-year-old loblolly pine plantation.
3. Natural shortleaf-Virginia pine, poor site.
4. Hardwood, selectively cut, good site.

Figure 1.--Germinated white oak acorn, showing emerged radicle. Acorns of the white oak group germinate in the fall and overwinter in this stage.

Acorns were planted in paired seed spots. One spot of each pair was protected with one-fourth-inch mesh hardware cloth screening (fig. 2), and the other was left unprotected. Seed spots under forest cover types were located in small openings. The field design is illustrated below:

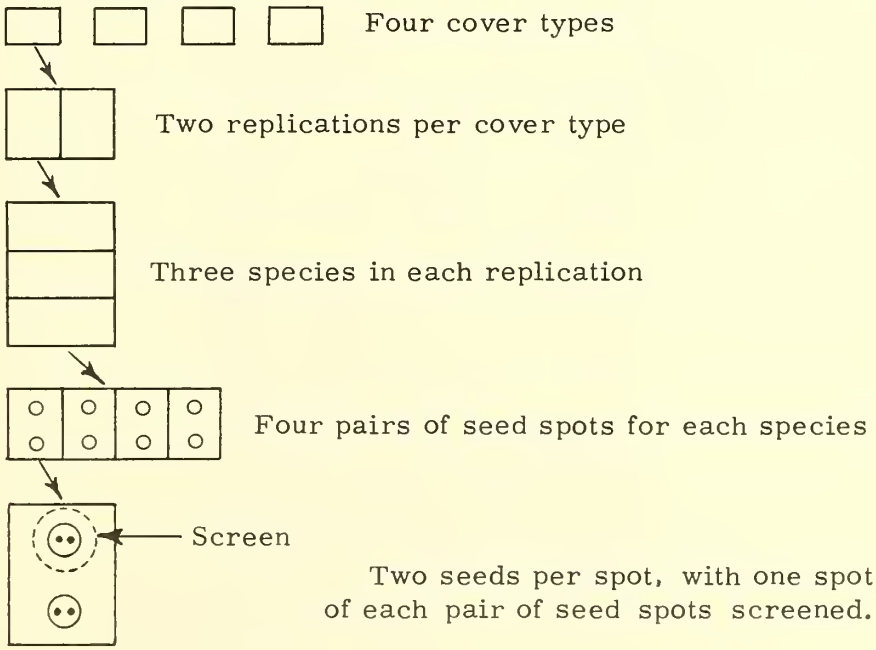
Four cover types
Two replications per cover type
Three species in each replication
Four pairs of seed spots for each species
Screen
Two seeds per spot, with one spot of each pair of seed spots screened.

Figure 2.--Screen protection used in the Piedmont. No screened acorns were taken by animals in this study.

Traps baited with acorn cotyledons and peanut butter were used to sample the rodent population to determine some of the species that consume acorns. Trapping was done during a 48-hour period each month from October 1956 through April 1957. Animals were collected once each 24 hours during the 2-day period and preserved for identification.

Mountains

The first study at Bent Creek was installed in December 1958 and April 1959. Six treatments involving variation in time of sowing, depth of seed placement, and protection from predators were arranged in a Latin Square design. Treatment combinations were as follows:

Season	Planting Depth	Protection
Fall	Surface	No screens
		Screens
	1 to 2 inches	No screens
		Screens
Spring	Surface	No screens
	1 to 2 inches	No screens

In the second study, installed December 1959 and April 1960, screens were used in the spring as well as in the fall, making a total of eight treatment combinations for a complete factorial design. The treatments shown below were arranged in a randomized block field design with five replications.

Season	Planting Depth	Protection
Fall	Surface	No screens
		Screens
	1 to 2 inches	No screens
		Screens
Spring	Surface	No screens
		Screens
	1 to 2 inches	No screens
		Screens

In both studies, fall planting was done with unstratified acorns and spring planting was done with stratified, sprouted acorns. A treatment plot consisted of 16 acorns spaced 2 feet by 2 feet. Hardware cloth of one-fourth-inch mesh was used for screen protection (fig. 3). Survival counts were made during the first growing season following installation. Plantings were done in large openings in stands of yellow-poplar; a separate opening was used for each test. Screens were removed in April in the first test and on June 30 in the second test.

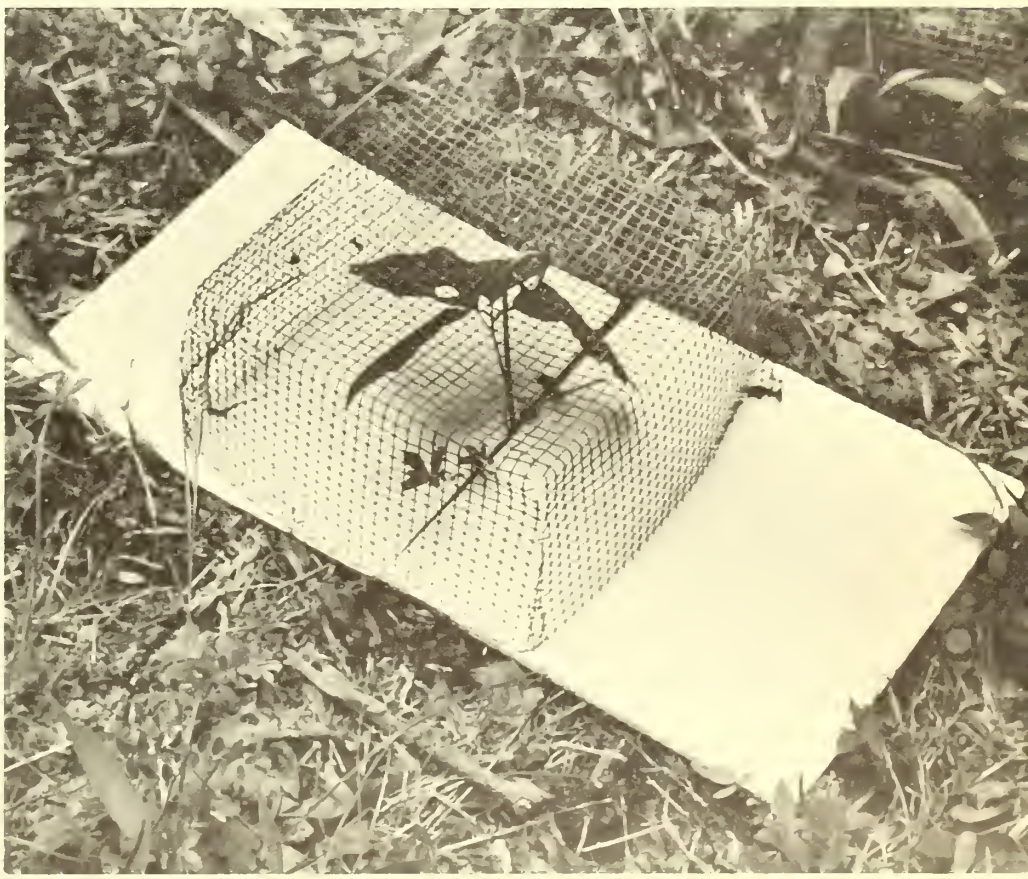

Figure 3.--A screen used in the mountain study. The white cards were used only for photographic purposes. Screens had no significant effect on seedling establishment in the mountain studies.

RESULTS

Piedmont

Screens were removed and a survival count was made on June 11, 1957. Only 37 out of 192, or 19 percent, of the exposed acorns had been eaten by animals, and none of the protected acorns were taken. There were no significant differences in rodent depredation associated with oak species or cover type. Analysis of the germination data as survival of individual plants and as percent of seed spots stocked revealed the following (table 1):

1. Northern red oak had the best individual acorn germination and the highest number of seed spots stocked, black oak was intermediate, and white oak ranked lowest.
2. Screen protection gave significantly higher individual plant survival, but did not result in a significant improvement in percent of seed spots stocked with at least one seedling.

A final inspection of the study was made on May 7, 1959, to determine subsequent survival (table 1). Mortality of northern red oak and black oak was three to four times greater than for white oak. White oak had the highest survival and percent stocking, black oak was intermediate, and northern red oak was lowest. This was the reverse of the species rankings two months after germination, and indicates the greater tolerance of white oak.

Several species of seed-eating animals were captured in the study area, but the whitefooted mouse (Peromyscus leucopus leucopus) appeared to be the most prevalent (table 2). Analysis of the trapping results indicated that the hardwood and old field habitats had higher rodent populations than the pine stands; however, populations appeared to be rather variable in all habitats.

Table 1. --Piedmont survival and seed spot stocking in June 1957 and May 1959 [1/]

PROTECTED SEED SPOTS [2/]

Date	White oak		Black oak		Northern red oak	
	Survival	Stocking [3/]	Survival	Stocking	Survival	Stocking
	Percent					
June 1957	56	88	78	94	95	100
May 1959	50	79	46	64	52	68
UNPROTECTED SEED SPOTS						
June 1957	53	72	58	75	82	100
May 1959	40	62	34	57	30	39
ALL SEED SPOTS						
June 1957	54	80	68	84	88	100
May 1959	45	71	40	61	41	54

1/ The 1959 data do not include one old-field replication and an additional old-field plot of white oak, which were destroyed in lake bed clearing.

2/ Data for all cover types were combined, since the effect of cover type on survival was not significant.

3/ Percent of seed spots containing at least one seedling.

Table 2. --Animals trapped on the Piedmont study area 1/

Common name	Scientific name	Total taken	Months taken
Shorttail shrew	Blarina brevicaudo carolinensis	3	October February March
Whitefooted mouse	Peromyscus leucopus leucopus	8	October November February April
Golden mouse	Peromyscus nuttalli	2	December April
Meadow vole	Microtus pennsylvanicus pennsylvanicus	4	October November January March
Eastern harvest mouse	Reithrodontomys humilis humilis	3	October November December
Pine mouse	Pitymys pinetorum pinetorum	2	February April
Field sparrow	Spizella pusilla pusilla	1	February
Total		23	

1/ Animal identifications were made by Dr. F. S. Barkelow, Head, Department of Zoology, North Carolina State College.

Mountain Study 1

Analyses of variance of survival revealed highly significant differences among treatments for each of the five examination dates (table 3). Sprouted acorns planted 1 to 2 inches deep in the spring gave better results during most of the first growing season than all other treatments. By September 16, however, survival for the treatment had dropped to the level of survival for acorns planted 1 to 2 inches deep under screens in the fall.

Screen protection did not significantly increase survival regardless of whether the fall-sown acorns were placed on the surface or planted 1 to 2 inches deep. Survival on May 29 was 51.0 percent and 46.9 percent, respectively, for screened vs. unscreened acorns planted in the soil, and was 1.0 percent and 2.1 percent, respectively, for screened vs. unscreened surface-sown acorns.

Treatments in which acorns were planted 1 to 2 inches deep gave better results than the treatments involving surface planting. Sprouted acorns sown on the surface in the spring gave significantly better early-season survival than acorns sown on the surface in the fall; the differences, however, had disappeared by the end of the season.

Table 3. --Average survival of northern red oak by date and treatment, Mountain Study 1

Season	Depth	Protection	Date of examination				
			May 7	May 29	June 22	July 17	Sept. 16
			Percent				
Fall	Surface	No screens	3.1	2.1	1.0	1.0	1.0
		Screens	1.0	1.0	3.1	4.2	3.1
	1 to 2 inches	No screens	38.5	46.9	41.7	40.6	31.2
		Screens	39.6	51.0	51.0	50.0	46.9
Spring	Surface	No screens	21.9	13.5	7.3	6.2	5.2
	1 to 2 inches	No screens	64.6	73.9	68.7	68.7	50.0

Only four whitefooted mice were captured during the limited amount of trapping done on the test site. No trapping was done during the dormant season. Observations indicated, however, that rodents were probably active during most of the winter and early spring. Many of the acorns on the surface under screens were taken by rodents that burrowed up from beneath. Browsing of the seedlings by deer resulted in slow growth and considerable mortality, causing at least part of the decline in survival during the summer.

Mountain Study 2

Screens were removed from all seed spots on June 30, and a survival count made (table 4). Tests of significance among survival means showed that spring planting 1 to 2 inches deep with screen protection was better than all other treatment combinations (100 percent survival), while sowing on the surface without screens in spring gave the poorest results (8.1 percent survival). Acorns which were fall-planted in the ground without screens had better survival than those which were fall-planted in the ground with screen protection; survival was, respectively 89.2 percent and 74.5 percent.

Table 4. --Average percent survival of northern red oak acorns, Mountain Study 2

Season	Depth	Protection	Average survival 1/
			Percent
Spring	1 to 2 inches	Screens	100.0
Fall	1 to 2 inches	No screens	89.2
Fall	1 to 2 inches	Screens	74.5
Spring	1 to 2 inches	No screens	68.9
Fall	Surface	No screens	23.4
Spring	Surface	Screens	22.7
Fall	Surface	Screens	18.9
Spring	Surface	No screens	8.1

1/ Survival means were compared by Duncan's Multiple Range Test. The means bracketed by any one line do not differ significantly at the 5-percent level of testing.

The survival values in table 4 represent the total effect of the different treatment combinations. Each of the eight treatments was some combination of the three factors tested--season of sowing, depth of sowing, and degree of protection. The study was so designed that the separate or "independent" effect of each factor could be determined, as well as the effect of holding any one factor constant while either or both of the other factors were varied. Thus it was possible to determine the average independent effect of

screens, for instance, or to determine the effect of screens in the fall vs. the effect of screens in spring, as another example.

Percent of seedling establishment is of primary interest in the study. However, in order to determine the fate of each acorn and thereby to understand more clearly the effect of each factor on survival, a tally of the rotten and missing acorns was made during the June 30 survival count (table 5). Analyses of the survival and the missing and rotten acorn data in table 5 were made to determine the effects of each of the three factors tested, as well as the interactions between and among them.

Table 5. --Percent of northern red oak acorns surviving, missing, or rotten on June 30, 1960, Mountain Study 2 1/

Season	Depth	Protection	Surviving	Missing	Rotten
				Percent	
Fall	Surface	No screens	23.4	65.0	7.7
		Screens	18.9	0.5	79.0
	1 to 2 inches	No screens	89.2	0.3	8.3
		Screens	74.5	0.0	25.5
Spring	Surface	No screens	8.1	83.5	4.4
		Screens	22.7	0.3	66.5
	1 to 2 inches	No screens	68.9	17.2	3.6
		Screens	100.0	0.0	0.0

1/ The percentages do not always add to 100 because a few acorns were still present which were neither rotten nor established as seedlings.

SURVIVAL

Neither screens nor planting season had, on the average, a significant independent effect on seedling establishment. The average effect of screen protection was to increase survival by 1.8 percent (table 6, under "Effect mean," line "P"). Spring planting, as compared with fall planting, increased seedling establishment by only 0.1 percent on the average (table 6, under "Effect mean," line "S").

The effects of planting depth and the screen protection X planting season interaction were highly significant. The average effect of planting acorns 1 to 2 inches deep, as compared with surface sowing, was to increase seedling establishment by 48.9 percent. The interaction between screen protection and planting season is illustrated in two places in table 6. In the interaction values under "Season," line "P," are the values -5.1 percent, representing the effect of screens on survival of fall-planted acorns, and 8.7 percent, representing the effect of screens on survival of spring-planted acorns. That is, screens decreased survival of acorns planted in the fall by 5.1 percent, but increased survival of spring-planted acorns by 8.7 percent. The effect of spring planting in the presence and absence of screens is shown in the table, line "S,"

Table 6. --Factorial mean effects and interaction values for surviving, missing, and rotten acorns of northern red oak, Mountain Study 2

SURVIVAL

Factorial effect 1/	Effect mean	Screens		Depth		Season	
		Absent	Present	Surface	1 to 2 inches	Fall	Spring
	Percent	- - - - - - - - - -		Interaction values (percent)		- - - - - - - - - -	
P	1.8	--2/	--	1.4	2.2	-5.1	8.7
D	48.9**	48.5	49.3	--	--	47.8	50.0
S	0.1	-6.8	7.0	-1.0	1.2	--	--
PS	6.9**	--	--	5.3	8.5	--	--
				MISSING ACORNS			
P	-33.0**	--	--	-46.2	-19.8	-30.7	-35.3
D	-17.6**	-30.8	-14.4	--	--	-17.8	-17.4
PD	13.2**	--	--	--	--	13.9	12.5
S	2.0**	4.3	-0.3	1.8	2.2	--	--
PS	-2.3**	--	--	-1.6	-3.0	--	--
				ROTTEN ACORNS			
P	15.8**	--	--	29.8	1.8	17.2	14.4
D	-14.5**	-0.5	-28.5	--	--	-13.1	-15.9
PD	-14.0**	--	--	--	--	-13.1	-14.9
S	-4.0**	-2.6	-5.4	-2.7	-5.3	--	--

1/ P = Effect of screen protection.
D = Effect of planting 1 to 2 inches deep rather than on the surface.
S = Effect of planting in the spring rather than in the fall.
PD, PS = Interactions.

2/ Dashes occur where interactions are meaningless.

** Significant at the 1 percent probability level.

under "Screens." Spring planting gave 6.8 percent lower survival than fall planting when screens were not used, but when screens were used the effect of spring planting was to increase survival by 7.0 percent. Failure of screens to have the same effect in both planting seasons, and failure of spring planting to have the same effect in the presence or absence of screens, accounts for the highly significant screen X season interaction. The average interaction was 6.9 percent as shown in the "Effect mean" column of table 6.

Missing Acorns

All three factors--protection, planting depth, and season--had highly significant effects on the percent of acorns that were eaten or carried away by animals. Screen protection decreased the number of acorns taken by 33.0 percent. Planting 1 to 2 inches deep, as compared with surface sowing, gave a 17.6 percent decrease in acorn loss. Spring planting increased the number of acorns missing by 2.0 percent over that of fall planting (table 6).

Two highly-significant interactions were revealed by the analysis of missing acorn data. Screens decreased acorn loss by 46.2 percent when acorns were left on the surface, but only by 19.8 percent when they were planted 1 to 2 inches deep. In turn, planting 1 to 2 inches deep, as compared

with surface sowing, decreased loss by 30.8 percent when screens were absent and only by 14.4 percent when screens were used. Screens were less effective in fall than in spring, and more of the spring-planted acorns were taken from plots without screens than from those with screens.

Rotten Acorns

Screens increased the number of acorns that rotted by 15.8 percent, while planting 1 to 2 inches deep and spring sowing, respectively, decreased rotting by 14.5 percent and 4.0 percent (table 6). The interaction between screen protection and planting depth was highly significant. Screens increased acorn rotting by 29.8 percent when acorns were left on the surface, but only by 1.8 percent when acorns were planted 1 to 2 inches deep. Planting to a depth of 1 to 2 inches decreased rotting by 0.5 percent and 28.5 percent, respectively, when screens were absent or present.

DISCUSSION

It is clearly evident from these study results that direct-seeded acorns should be planted in the ground rather than merely placed on the surface. Uniformly good survival occurred in the Piedmont study in which all the acorns were planted in the soil. In the two mountain studies, planting depth proved to be the most important factor tested. It was the only factor which had a significant independent effect on seedling establishment in the second mountain study.

Spring planting in the ground had a definite advantage over fall planting in the ground, as well as a definite disadvantage. Only good, sprouted acorns were used in spring. The acorns which were planted in the fall had been immersed in water to separate the defective acorns, but since this method is not completely effective (Korstian, 1927), some of the fall-planted acorns very likely were defective. The disadvantage in spring planting was that the food supply is shortest at this time of year, resulting in greater predation pressure. Apparently the spring-planted acorns were easier to find than the fall-planted acorns during this period of low food supply, perhaps because of the freshly-disturbed spot of soil at each acorn. Soil disturbed in fall-planting had settled firmly into place and possibly had been covered by leaves and other litter. In Mountain Study 2, 17.2 percent of the acorns that were spring-planted 1 to 2 inches deep without screens were taken by animals, whereas only 0.3 percent of the acorns planted similarly in the fall were taken.

The effect of screens on seedling establishment was inconsistent in the three studies. Screens increased survival in the Piedmont study, but not in the two mountain studies. In Mountain Study 2, they decreased survival of acorns fall-planted in the ground. None of the screened acorns were taken by animals, and less than 1 percent of the unscreened ones were taken, but considerably more of the screened acorns rotted than did the unscreened ones. Perhaps the screens prevented leaves and other litter from accumulating on the protected spots. The mulching effect of litter on unscreened spots and the

lack of it on screened spots, even though both lots of acorns were planted in the ground, may have caused the difference in survival of the two lots of acorns.

Survival results showed that surface-sowing of acorns was an ineffective method of reproducing northern red oak; the missing and rotten acorn data revealed why. When acorns on the surface were not protected by screens many were taken by animals. When screens were used, however, the acorns were not taken, but rotted. In either case, survival was too low to be satisfactory.

SUMMARY

Results of three tests of direct seeding of oaks, one in the Piedmont and two in the mountains of North Carolina, indicate that white, northern red, and black oaks can be successfully regenerated by direct seeding. Best results were obtained with acorns that were planted in mineral soil. Screen protection, though effective, proved to be unnecessary in the Piedmont study where all the acorns were planted in the soil. In the mountain studies screens were ineffective; survival of acorns on the surface was very low regardless of screen protection, while results were good with acorns planted in the soil, whether screens were used or not. Acorns used for direct seeding should be treated for weevil control and planted 1 to 2 inches deep in mineral soil. Planting may be done either in the fall or in the spring.

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